Water-Soluble Flavor and Odor Precursors of Meat. 4. Influence of Cooking on Nucleosides and Bases of Beef Steaks and Roasts and Their Relationship to Flavor, Aroma and Juiciness

SUMMARY—Cooking resulted in significant increases in adenylic acid, total purine nucleosides and bases of 80 beef roasts of eight different cuts. It decreased the contents of inosinic acid, guanylic acid and sum of individual nucleotides (adenylic, cytidylic, uridylic, inosinic and guanylic acids) in these samples. Significant differences were also found between the various constituents of raw and cooked samples of the beef cuts.

INTRODUCTION

THE IMPORTANCE and interest in the nucleoside content of meat was outlined by Macy et al. (1970) and the subject has been discussed comprehensively (Kuninaka, 1967).

The work described in the present paper is a continuation of study of the effect of heating on the nucleosides, nucleotides and bases of beef roasts.

EXPERIMENTAL

Sample preparation and extraction

Ten cuts were studied in these experiments (Table 1).

These cuts were selected randomly from groups of 12 to 31 samples each of the eight different cuts. These roasts had been stored frozen approximately six months prior to their study.

Raw samples from each frozen roast were sawed in 1/2 in. slices adjacent to the center cut portion which was subsequently cooked and analyzed subjectively. Lean portions of the cooked samples remaining after organoleptic evaluation were ground twice through a 1/8 in. plate immediately after cooking. Raw samples were ground in a similar manner.

Perchloric acid extracts were made of these samples by a method similar to that described by Macy et al. (1970). The difference was in the dilution volume employed.

Ion-exchange chromatography of nucleotides. The method of Macy et al. (1966) was used.

Ion-exchange chromatography and analyses of total nucleosides, nucleotides and bases. The method described by Jones et al. (1964) was used for these analyses.

Analyses for fat and moisture. These analyses were carried out by the standard methods of the A.O.A.C. (1960).

Statistical analyses. Analysis of variance was used to analyze the chemical data and significant differences between means of various groups of samples determined by Duncan's multiple range test (Duncan, 1955).

RESULTS & DISCUSSION

Effect of cooking on different beef cuts

Results of analysis of variance indicated that no significant ($P < 0.05$) differences existed between means of cytidylic acid of the different cuts of raw or cooked beef or between raw and cooked samples of the individual cuts.

Cooking significantly increased mean adenylic acid values in all eight beef cuts studied (Table 2). This substantiates results from earlier experiments for beef, lamb and pork (Macy et al., 1970). The increase in adenylic acid of these samples was probably due to availability of nucleotides and also the inactivation of adenylic deaminase. There was possibly some phosphomonoesterase activity prior to heat inactivation of indigenous enzymes.

The uridylic acid of the raw samples was rather constant and did not change appreciably during cooking (Table 3). Cooking resulted in diminished content of this nucleotide in samples analyzed but this generally was not a significant decrease.

Mean concentrations of inosinic acid of raw and cooked beef roasts are presented in Table 4. Among raw samples, Choice rib steaks contained less inosinic acid than did other cuts but not significantly less than Good calf clod roasts.

Cooking decreased the inosinic acid of all samples and most of these changes

Table 1—Beef cuts studied.

Type of beef cut	U.S.D.A. grade	Type of cookery	Internal temperature, °C
Rib	Good	2 in. broiler steak	66
Rib	Choice	2 in. broiler steak	66
Calf rib	Good	2 in. broiler steak	66
Clod	Choice	Pot roast	77
Calf clod	Good	Pot roast	77
Round	Choice	Roast	66
Round	Good	Roast	66
Calf round	Good	Roast	66

Table 2—Means of adenylic acid for raw and cooked beef steaks and roasts.

U.S. grade and cut[1]	Means of adenylic acid[2] (mg/100 g dry, fat-free tissue) Raw	Cooked[3]
Choice rib steaks	17.8 FG	33.5 C
Good rib steaks	21.3 DEF	36.2 ABC
Good calf rib steaks	24.4 DE	35.2 BC
Choice clod roasts	18.7 EFG	37.4 ABC
Good calf clod roasts	13.8 G	37.5 ABC
Choice round roasts	21.9 DEF	42.3 A
Good round roasts	15.9 FG	41.6 AB
Good calf round roasts	26.1 D	39.7 ABC

[1] Ten different samples of each cut were analyzed.

[2] Means followed by the same letter are not significantly different ($P < 0.05$).

[3] Rib steaks were broiled to 66°C; round and clod roasts were roasted to 66° and 77°C, respectively.

Table 3—Means of uridylic acid for raw and cooked beef steaks and roasts.

U.S. grade and cut[1]	Means of uridylic acid[2] (mg/100 g dry, fat-free tissue) Raw	Cooked[3]
Choice rib steaks	14.8 ABC	13.9 ABC
Good rib steaks	17.4 A	15.6 AB
Good calf rib steaks	17.3 A	13.9 ABC
Choice clod roasts	11.2 BCDE	8.1 E
Good calf clod roasts	13.0 ABCD	10.2 CDE
Choice round roasts	15.2 AB	8.3 DE
Good round roasts	16.2 AB	8.5 DE
Good calf round roasts	12.9 ABCD	11.5 BCDE

[1] Ten different samples of each cut were analyzed.

[2] Means followed by the same letter are not significantly different ($P < 0.05$).

[3] Rib steaks were broiled to 66°C; round and clod roasts were roasted to 66° and 77°C, respectively.

were significant. Inosinic acid of cooked samples varied significantly. The cooked rib steaks contained significantly more inosinic acid than did the other cuts and the clod roasts had less. The latter was undoubtedly due to the higher cookery end point.

Table 4—Means of inosinic acid for raw and cooked beef steaks and roasts.

U.S. grade and cut[1]	Means of inosinic acid[2] (mg/100 g dry, fat-free tissue) Raw	Cooked[3]
Choice rib steaks	269 DE	230 EF
Good rib steaks	322 BC	252 E
Good calf rib steaks	352 AB	250 E
Choice clod roasts	363 A	123 I
Good calf clod roasts	304 CD	122 I
Choice round roasts	339 ABC	131 I
Good round roasts	371 A	158 HI
Good calf round roasts	343 ABC	201 FG

[1] Ten different samples of each cut were analyzed.
[2] Means followed by the same letter are not significantly different ($P < 0.05$).
[3] Rib steaks were broiled to 66°C; round and clod roasts were roasted to 66° and 77°C, respectively.

Table 5—Mean values for ratios of adenylic acid to inosinic acid of raw and cooked beef roasts.

U.S. grade and cut[1]	Mean values for ratios[2] Raw	Cooked[3]
Choice rib steaks	0.066 E	0.148 CD
Good rib steaks	0.067 E	0.145 CD
Good calf rib steaks	0.071 E	0.144 CD
Choice clod roasts	0.052 E	0.332 A
Good calf clod roasts	0.047 E	0.327 A
Choice round roasts	0.067 E	0.340 A
Good round roasts	0.048 E	0.343 A
Good calf round roasts	0.080 DE	0.207 BC

[1] Ten different samples of each cut were analyzed.
[2] Means followed by the same letter are not significantly different ($P < 0.05$).
[3] Rib steaks were broiled to 66°C; round and clod roasts were roasted to 66° and 77°C, respectively.

Table 6—Means of guanylic acid for raw and cooked beef roasts.

U.S. grade and cut[1]	Means of guanylic acid[2] (mg/100 g dry, fat-free tissue) Raw	Cooked[3]
Choice rib steaks	16.5 CDE	10.3 EFGH
Good rib steaks	11.9 EFG	10.4 EFGH
Good calf rib steaks	27.1 A	22.2 ABC
Choice clod roasts	9.1 FGHI	4.4 HIJ
Good calf clod roasts	15.5 DE	8.0 GHIJ
Choice round roasts	19.6 BCD	5.4 HIJ
Good round roasts	3.3 IJ	2.1 J
Good calf round roasts	24.3 AB	14.8 DEF

[1] Ten different samples of each cut were analyzed.
[2] Means followed by the same letter are not significantly different ($P < 0.05$).
[3] Rib steaks were broiled to 66°C; round and clod roasts were roasted to 66° and 77°C, respectively.

The relationship between adenylic acid and inosinic acid is important because adenylic acid is the immediate precursor of inosinic acid, and the latter, the most abundant nucleotide in the beef tissue, is believed to be an important flavor enhancer (Kuninaka et al., 1964; Kurtzmann et al., 1964; Shimazono, 1964; Wagner et al., 1963). The mean ratios of adenylic acid to inosinic acid for the different cuts of raw and cooked beef are presented in Table 5. No significant differences were found between these values for the different raw samples.

The ratios of adenylic acid to inosinic acid for the different cooked cuts could be divided into three distinct groups. First, values for rib steaks from Choice, Good and calf did not differ significantly. Ratios for these cuts were significantly lower than those of the other cuts except Good calf round roasts which were not significantly different. Second, mean ratios for Choice and calf clod roasts, and Choice and Good round roasts were significantly higher than those of the other beef cuts. Third, ratios for Good calf round roasts were intermediate between values for the first two groups.

In all comparisons, ratios of adenylic acid to inosinic acid were significantly higher for cooked than for corresponding raw cuts. This is a reflection of the increase in adenylic acid and the decrease in inosinic acid during cooking at these temperatures.

Mean guanylic acid concentrations of the eight cuts of raw and cooked beef are presented in Table 6. Significant differences were observed in this constituent for the various raw and cooked samples. These differences were irregular except that, in general, the calf samples contained greater amounts of guanylic acid than more mature beef. Guanylic acid was low in concentration compared to inosinic acid. This finding confirms previously discussed results (Macy et al., 1970), where guanylic acid was found to be low in concentration in beef, pork and lamb as well as labile to heat. This is an important finding since this compound is thought to influence flavor desirability.

Means of the sums of individual nucleotides (adenylic, cytidylic, uridylic, inosinic and guanylic acids) of the eight raw and cooked cuts are outlined in Table 7. Since inosinic acid was the predominant nucleotide of beef and was destroyed by cooking, differences in total nucleotides were similar to those of inosinic acid. There was appreciable loss in nucleotides of all samples during cookery, particularly cooked to a higher point.

Total nucleotides of cooked and raw beef determined by the modified method of Jones et al. (1964) are presented in

Table 7—Mean values for sums of individual nucleotides for raw and cooked beef roasts.

U.S. grade and cut[1]	Means of sums of nucleotides[2] (mg/100 g dry, fat-free tissue) Raw	Cooked[3]
Choice rib steaks	332 DEF	302 FG
Good rib steaks	377 BCD	330 EF
Good calf rib steaks	437 A	335 DEF
Choice clod roasts	419 AB	186 J
Good calf clod roasts	365 CDE	192 J
Choice round roasts	409 ABC	200 J
Good round roasts	420 AB	223 IJ
Good round roasts	403 ABC	247 HI
Good calf round roasts	425 A	276 GH

[1] Ten different samples of each cut were analyzed.
[2] Means followed by the same letter are not significantly different ($P < 0.05$).
[3] Rib steaks were broiled to 66°C; round and clod roasts were roasted to 66° and 77°, respectively.

Table 8—Mean values for total nucleotides of raw and cooked beef steaks and roasts.[1]

U.S. grade and cut[2]	Means of total nucleotides[3] (mg/100 g dry, fat-free tissue) Raw	Cooked[4]
Choice rib steaks	299 CDE	313 BCDE
Good rib steaks	487 A	302 BCDE
Good calf rib steaks	370 BC	300 CDE
Choice clod roasts	370 BC	206 FG
Good calf clod roasts	351 BCD	198 G
Choice round roasts	345 BCD	233 EFG
Good round roasts	341 BCD	244 EFG
Good calf round roasts	355 BCD	285 CDEF

[1] Batchwise method of Jones et al. (1964).
[2] Ten different samples of each cut were analyzed.
[3] Means followed by the same letter are not significantly different ($P < 0.05$).
[4] Rib steaks were broiled to 66°C; round and clod roasts were roasted to 66° and 77°C, respectively.

Table 9—Means for total purine nucleosides and bases of raw and cooked beef steaks and roasts.[1]

U.S. grade and cut[2]	Means for total purine nucleosides and bases[3] (mg/100 g dry, fat-free tissue) Raw	Cooked[4]
Choice rib steaks	252 GHI	269 FGH
Good rib steaks	231 I	273 EFGH
Good calf rib steaks	251 GHI	267 FGH
Choice clod roasts	289 DEF	289 DEF
Good calf clod roasts	302 CDE	296 CDEF
Choice round roasts	278 EFG	326 ABC
Good round roasts	247 HI	313 CD
Good calf round roasts	310 CD	351 A

[1] Batchwise method of Jones et al. (1964).
[2] Ten different samples of each cut were analyzed.
[3] Means followed by the same letter are not significantly different ($P < 0.05$).
[4] Rib steaks were broiled to 66°C; round and clod roasts were roasted to 66° and 77°, respectively.

Table 8. Total nucleotides of raw beef samples were generally lower than the sums of individual nucleotides for the same samples. The exception to this observation was for Good rib roasts. Variation in total nucleotides of the cooked cuts was similar to that for sums of individual nucleotides analyzed.

There was very little difference between means for total nucleotides among the various groups of raw samples. Cooking significantly decreased total nucleotides in most samples analyzed. There were differences in total nucleotides among the cooked samples of the various cuts but many of these were insignificant.

Results of total purine nucleoside and base determinations of raw and cooked beef are in Table 9. The three cuts of raw rib roasts contained significantly less total purine nucleosides and bases than the raw clods, and Good calf rounds. Highest quantity of purine nucleosides and bases among the raw samples was in Good calf rounds. This was significantly higher than that found in other cuts of raw beef except clod roasts which were not significantly different. Other significant differences in total purine nucleosides and bases existed among the cooked samples; however, no particular trend was evident.

In general, cooking resulted in increased quantities of purine nucleosides and bases. Significant increases in total purine nucleosides and bases due to cooking were found in the Good rib steaks and in the round roasts. It has been thought that larger increases in total purine nucleosides and bases would be found in the different cuts of beef and that increases due to cooking would have been significant in all cases, since rather large amounts of inosinic acid were destroyed. Degradation of all nucleotides should contribute to increases in total nucleosides and bases.

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